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New Bio-Solvent Extraction Process Used in Commercial Development of Utah Oil Sands

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ABSTRACT

US Oil Sands' proprietary bitumen extraction technology is designed to cost effectively recover over 90% of the bitumen from the ore processed using a unique bio-solvent based design. The technology has been successfully piloted since 2005 with Athabasca and Utah oil sands of varying ore grades and qualities, with oil sands consisting of both water-wet and oil-wet properties. Based on these results, US Oil Sands is currently constructing the first commercial demonstration unit on its Utah leases called PR Spring with a capacity of 2,000 barrels bitumen per day. The technology is both suitable and ready for commercialization for Athabasca bitumen and the company is actively advancing the development of this technology in this region. When compared to other traditional extraction technologies, the process has several environmental advantages including the elimination of tailings ponds, significant reduction in GHG emissions, smaller mining footprint, and best in class water use and recycle. The economic benefits include low up front capital cost and significant reduction in equipment costs when compared to traditional extraction processes. In addition, the low capital cost enables small mine developments as low as 10,000 barrels per day allowing for exploitation of leases considered too small for large scale projects. These "stranded" mining opportunities can therefore be developed economically.

This paper provides a description of the process, the pilot results achieved, the economic and environmental advantages for both oil-wet and water-wet oil sands, and the path to full scale commercialization of the technology in Utah and Athabasca oil sands.

KEY WORDS

Utah Oil Sands, Bitumen Solvent Extraction Technology, Pilot Plant, Athabasca Bitumen Solvent Extraction.

INTRODUCTION

US Oil Sands Inc. ("**USO**" or the "**Company**") plans to construct and operate the PR Spring Project Phase I (the "**Project**"). The Project will be located at USO's 100% working interest 5,930 acre PR Spring Development Area located in northeast Utah on the East Tavaputs Plateau, approximately 80 miles south of Vernal, Utah. The Project will be designed to commercially demonstrate the Company's proprietary bitumen extraction process under actual field conditions. It will produce up to 2,000 barrels per day of bitumen.

The Company's revolutionary bitumen extraction process uses a bio-solvent to efficiently extract bitumen from surface mineable oil sands. The Company's unique and low cost extraction process is the first commercial application to extract bitumen from the challenging oil-wet sands of Utah. The addition of a bio-solvent in the Company's extraction process rapidly liberates the hydrocarbons without forming middling sludge. The process uses low mechanical energy which avoids the shearing of clays and allows for simple fine solids separation using standard extraction equipment, removing the need for tailings ponds and thereby allowing concurrent reclamation of mine pits. The Company is targeting sustained

bitumen recoveries exceeding 90% while recycling 98% of the bio-solvent and 95% of the process water engaged.

The elimination of expensive water handling, bitumen froth treatment, middling sludge management and tailings storage/rehandling allows USO's proprietary extraction process to be a low cost alternative to typical multi-billion dollar surface oil sands mining operations. USO's process has been extensively tested at the Company's operations facilities in Grande Prairie, Alberta in a nominal 25 barrel per day pilot unit.

The Project is aimed at demonstrating the commercial viability of the process in a safe manner with a robust approach to the design. Data collection is also a major objective of the Project in order to optimize designs for subsequent larger scale commercial projects. The Project will have a small footprint and will be designed and operated to meet or exceed all environmental regulations. Project facilities will be designed for an anticipated 20 year operating life, with start-up planned for late 2015.

USO BIO-SOLVENT TECHNOLOGY DESCRIPTION

USO's process is a patented technology for extracting bitumen from surface-mineable oil sand deposits. It is similar in general concept to the well-known Clark Hot Water Process which was developed in the 1920s and put into commercial operations in the 1960s to exploit the massive bitumen reserves in the Athabasca oil sands region of Alberta, Canada. Both methods require the oil sand ore to be mined and hauled to a processing facility for extraction of the bitumen and disposal of the produced sand tailings.

USO's extraction process (refer to Figure 1) is similar to the Clark Hot Water Process in that it also utilizes hot water to facilitate the separation of the bitumen from the host sand. The principal differences between the two processes is that USO's process utilizes an environmentally friendly non-petroleum-based organic solvent (bio-solvent) to achieve a high degree of separation (>90% bitumen recovery targeted) from the ore. The resultant clean sand tailings have been approved for disposal back to the mine pit without the requirement for a tailings pond.

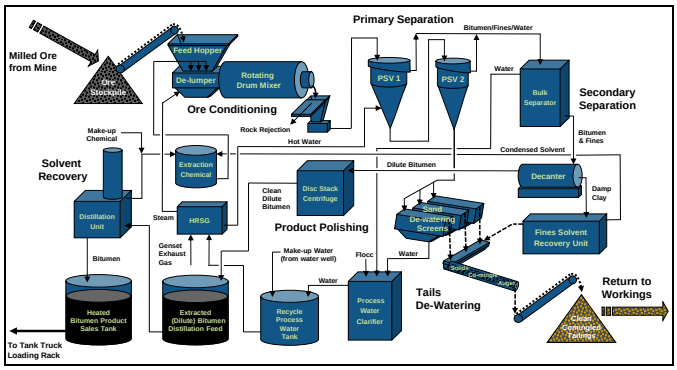
When examined more closely, USO's extraction process can be broken down into four principal (post mining) operations:

1. Ore conditioning
2. Separation
3. Product polishing and solvent recycle
4. Tailings dewatering and solvent recovery

Ore conditioning is the series of processes required to reduce the aggregate size of the mined ore to a dimension and consistency suitable for ingestion into the primary separation process. Separation is the core of the process, where the viscous bitumen is stripped from the host sandstone (comprised of quartz, feldspar, plagioclase and minor percentages of clay minerals) using heat, water and the bio-solvent. During the separation phase, the bio-solvent breaks the bitumen's bond with the sand and clays and then goes into solution with the liberated bitumen, acting as a diluent. The lower specific gravity of the resulting diluted bitumen allows for effective gravity separation from the water phase to occur.

The product polishing and solvent recycle segment of the process then separates the diluted bitumen from the clay fines and residual process water and removes the bio-solvent from the diluted bitumen to make final saleable bitumen product. Approximately 98% of the engaged bio-solvent is recovered with distillation and is recycled to a holding tank for re-use. In tailings dewatering and solvent recovery approximately 95% of the circulating process water is recovered from the produced sand and fines tailings to be recycled indefinitely until fractionally lost to tailings discharge.

Figure 1: Process Flow Diagram of USO's Extraction Process



TECHNOLOGY DEVELOPMENT HISTORY

During the initial three years of the Company's existence (2003 – 2005), prototype units ranging in size from 150 – 500 bbl/d were fabricated and tested, confirming the basic technology using the bio-solvent was viable and that bitumen could be extracted from the oil sands deposits at PR Spring.

From 2006 to 2008, USO initiated design and fabrication of a 25 bbl/d Shop Demonstration Unit ("**SDU**") in Grande Prairie for testing and collection of commercial engineering information. Completing the SDU in early 2007, the Company continued to investigate more efficient modifications for various aspects of the bitumen extraction process, including slurrying the conditioned oil sand with

process water and the bio-solvent prior to introduction to the separation vessels, methods to impart heat to this slurry, and gravimetric separation methods.

From 2009 to 2012, efforts continued in areas such as evaluations of quality of tailings, selection of methods to separate the middlings phase into a hydrocarbon rich stream and a water/solids rich stream and to purify the hydrocarbon phase prior to distillation, and scale-up engineering of the extraction process. Pilot tests of the Utah ore conducted with the SDU allowed for equipment selection, development of heat and material balances and engineering design for the commercial demonstration unit.

In 2012, basic engineering began for the first phase of the PR Spring Project for a 2,000 bbl/d Commercial Demonstration Unit ("**CDU**"). The main components of the basic engineering package included: i) material balance, ii) process flow diagram, iii) equipment list, iv) preliminary cost estimates, and v) general arrangement drawings. USO also completed field trials of its mining equipment in August 2012.

In 2014, USO transitioned to detailed engineering of the CDU and initiated procurement of long-lead delivery equipment components. Site work continued focusing on preparing the plant site to accept delivery of process extraction equipment modules, including site grading, construction of a warehouse and utility supply and roadway infrastructure.

So far in 2015, detailed engineering is approximately 60% complete and all major equipment components have been ordered. Site construction is scheduled to ramp up in March 2015 with construction completion expected in September 2015. Commissioning and start-up of the CDU is scheduled to occur in Fourth Quarter 2015 with first-oil expected soon after.

PILOT RESULTS

The SDU is an integral part of the technology development and improvement. It is capable of processing 800 kg/hour of ore and produces clean course sand, diluted bitumen and clay fines. The SDU does not have all the capability of the CDU to separate and recycle the solvent, but provides meaningful insight into separation efficiency of the bitumen from the sand and fines.

Most of the development work of the USO extraction process has been conducted with Utah oil sands. In a normal trial, in excess of 90% of the bitumen is extracted from the coarse solids. A summary of the results of a few sample runs of the SDU is set forth in Table 1.

Table 1: Selected Shop Demonstration Unit Trial Run Results

Trial Run (#)	Date	Ore Feedstock	Coarse Bitumen Extraction (%)	Residual Bitumen in Tailings (%)	Residual Solvent in Tailings (%)
30	Aug. 2/07	10.85 wt% Athabasca	95.76	0.46	0.00
91	Jun. 22/11	9.87 wt% Utah	97.24	0.27	0.01
94	Nov. 10/11	9.70 wt% Utah	98.84	0.11	0.00

In the early stages of the development process, the prototype units were operated using Athabasca ore and as development continued, the USO technical team wished to compare the performance of the process on Athabasca ore versus Utah ore. In March 2007, the Company received two truckloads of ore from a test pit in Athabasca. The Company conducted several trials using this ore and found that generally, the process worked as well on Athabasca ore as on Utah ore. More recently, in November 2014, 15 tonnes of Athabasca derived low grade ore with fines (<0.045mm) content 40%+ and average bitumen content 6.4 wt% was tested with the SDU. A summary of the extraction rates from the 2007 and 2014 Athabasca ore tests is set forth in Table 2.

Table 2: Shop Demonstration Unit Trial Run Results on Athabasca Ore

Trial Run	Date	Coarse Bitumen Extraction (%)
29	July 27, 2007	94.10
30	August 2, 2007	95.76
49	July 16, 2008	92.40
188	October 31, 2014	99.83
189	November 4, 2014	97.10
190	November 6, 2014	99.69

Despite the high fines and low bitumen content of the Athabasca ore tested in 2014, the test results showed exceptional extraction of the bitumen from the coarse sand. Athabasca ore testing in the SDU will continue in 2015 with the objective of testing process variable such as temperature and solvent addition rates.

ECONOMIC PERFORMANCE

The elimination of expensive capital infrastructure such as water handling, bitumen froth treatment, middling sludge management and tailings storage recovery allows the process

to be a low cost, scalable and modular alternative to typical multi-billion dollar surface oil sands mining operations.

The design of the processing units incorporates largely off-the-shelf equipment components leading to reduced fabrication schedules, reduced engineering and capital cost, and increased component and design reliability. The Company's processing units are skid-mounted and can be located next to the oil sands deposit, allowing for cost effective offsite fabrication and rapid field construction. Additionally, units can be scaled to match the size of the resource and are re-deployable to successive processing locations, driving-down mine lives and increasing project NPVs. The initial commercial unit of 2,000 bbl/d is expected to cost $60 million resulting in a capital efficiency of $30,000/bbl/d as compared to $100,000/bbl/d for conventional oil sands mining in Alberta. The Company expects increased efficiencies on subsequent process units thereby further enhancing the Company's capital efficiency to approximately $20,000/bbl/d.

Operating costs have been estimated based on plant design capacity, bitumen content in ore and resultant volume of ore to be processed to achieve the desired output using data from extensive testing of the Company's SDU and are estimated at between $27/bbl and $35/bbl (see Table 3) for both mining and extraction. The operating costs include labour, solvent make-up, utilities, maintenance, mining and a majority of the reclamation costs due to the fact that mined areas are immediately backfilled with clean tails. The Company expects per barrel production costs to decrease with higher capacity process units.

ENVIRONMENTAL PERFORMANCE

USO's innovative, yet simple modification to the traditional bitumen extraction process, creates a much smaller environmental footprint than other oil sands processing techniques. The Company's proprietary solvent is biodegradable and non-toxic, is extremely effective at oil separation and 98% of which is recovered and re-used. The process avoids the oily liquid tailings that other commercial oil sands mining projects generate and deposit into tailings ponds. USO's produced sand and fines are non-hazardous, clean and approved for immediate reclamation in the mined area[1]. This concurrent reclamation program is the first in oil sands mining and is a key component of the Company's environmental best practices. It is estimated that the Company's surface footprint will be 90% smaller than other projects (on a per barrel basis, at 10,000 bbl/d of production).

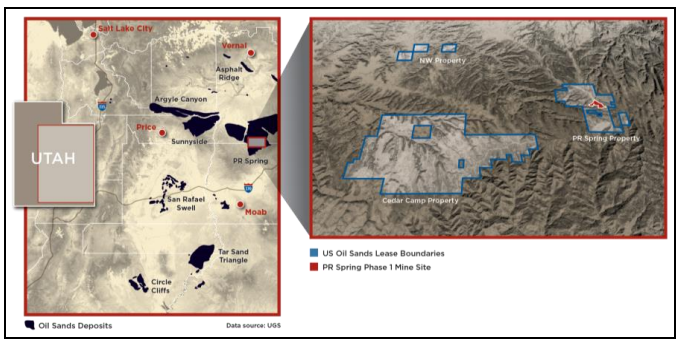
USO designed the extraction process to maximize recovery of water and to recycle as much as 95% of the process water, the highest recycle rate of any existing project. The only make-up water required is for that which leaves the system in the form of residual moisture in the clean (inert), "damp-dry" produced sand tailings. For every barrel of bitumen produced, an estimated 1.5 – 2 barrels of water is consumed compared to three[2] to seven[3] barrels of water traditional oil sands mining projects use. An important distinction of traditional mining operations is that, while ultimately recycled, water sits in tailings ponds for long periods of time and initial water use can be as high as 10 barrels per barrel of bitumen produced. USO's process however, immediately recycles the water, thereby minimizes the amount of heating required and captures and reuses waste heat to minimize heating requirements for make-up water. In turn, this reduces the greenhouse gases generated by the facility, and the energy usage.

It's expected USO's process will require only one-half of the energy of existing SAGD processes. The project also claims the highest oil recovery efficiency of any oil sands project, thereby also reducing its per barrel greenhouse gas profile. Overall, the bitumen extraction process developed by USO is best-in-class in terms of environmental impacts from operations, with an EROI (energy return on investment) of 12:1 compared to approximately 10:1 for typical mining oil sands operations[4] and approximately 6:1 for typical *in-situ* oil sands operations[5].

PR SPRING UTAH PROJECT

The target production rate for the Project's oil sand processing plant is 2,000 bbl/d from a single production train. Production at 2,000 bbl/d from the Project's mine site will require an ore feed rate of approximately 4,400 tons (4,000 tonnes) per operating day at a grade of 8.65% bitumen with a target bitumen recovery of approximately 95%. Phase 1 will be followed by an expansion to increase capacity up to 10,000 bbl/day. The timing of the expansion will depend on the results acquired from the initial development phase. USO has a 100% working interest in 5,930 acres (see Figure 2) with an estimated 184 MMbbls Discovered Resource[6].

Figure 2: Map of USO's Oil Sands Leases



USO's PR Spring mine site is located in a relatively remote area of eastern Utah, on the high Tavaputs Plateau (elevation 8,150 ft. above sea level). Present road access is a 73 mile drive (via paved highway) south of the intersection of US Highway 40 and Highway 88 on County Road 2810 (Seep Ridge Secondary Highway).

Oil sand originating from the PR Spring deposit is known to have an average bitumen content of approximately 7-12%, is considered "semi-oxidized" by Athabasca criterion and is contained within a highly consolidated sandstone matrix. Individual sand grains have a wider gradation band and more angular geometry when compared to the grain characteristics of Athabasca ores. Connate water content is approximately 1% (i.e. the ore is oil-wet rather than water-wet as it is in Athabasca).

The in-situ fines content (particles <45 μm) of PR Spring ore is approximately 17% with a range of 10-25%. Fines are predominantly composed of shales, siltstones, mudstones and clays. The oil-wet ore found in Utah's oil sands deposits is typically more consolidated and abrasive than its Canadian counterparts in Athabasca. A Wirtgen surface miner will be used and can withstand the abrasive, consolidated nature of this ore yet selectively mine the most desirable areas of a deposit with minimal ingestion of undesirable/barren materials. The Wirtgen surface miner will be supported by a small fleet of elevating scrapers to selectively load and haul ore to the extraction plant. Scrapers hauling milled ore to the plant will backhaul co-mingled sand/fines tailings to the mined out areas of the working pit as the first step of the Company's concurrent reclamation program.

The ore process train is designed to accommodate approximately 4,400 tons (4,000 tonnes) of ore per day, producing approximately 2,000 bbl/d of bitumen. Water is expected to be consumed at a rate of approximately 1.5 – 2 barrels for each barrel of produced bitumen. The 2,000 bbl/d operation would use up to 4,000 barrels of water per day, or 116 gallons per minute based on 24-hour processing. The majority of the water "consumed" in the process is simply returned to the environment as un-recoverable entrained moisture in the pore spaces of the produced sand and clay fines. Most of this residual water is anticipated to evaporate from the loosely consolidate produced sand/fines mix with no free-water run-off.

Costs have been estimated based on plant design capacity, bitumen content in ore and resultant volume of ore to be processed to achieve the desired output. Data from extensive testing of the Company's SDU was also gathered and incorporated into the extraction cost estimates. As detailed in Table 3, USO has also prepared initial extraction cost estimates based on a low oil price environment. Cost reductions are principally achieved through reduced fuel costs and labour rates, and operating efficiencies.

Table 3: PR Spring Project Phase 1 Production Costs

	Per Barrel Production Costs	
	Base Case ($/bbl)	**Low Oil Price Case** ($/bbl)
Labour, subsistence, travel	6.64	4.00
Bio-solvent	6.19	6.00
Utilities (energy and water)	3.35	3.35
Disposals	0.10	0.10
Maintenance and field office	0.81	0.70
Maintenance contingency	1.50	1.00
Extraction Costs	**18.59**	**15.15**
Mining Costs	16.00	12.00
Total Production Costs	**34.59**	**27.15**

In 2014, USO transitioned to detailed engineering following project sanctioning of the CDU and initiated procurement of long-lead delivery equipment components. Site work continued focusing on preparing the plant site to accept delivery of process extraction equipment modules, including site grading, construction of a warehouse and utility supply and roadway infrastructure.

As of February 15, 2015, detailed engineering is approximately 60% complete and all major equipment components have been ordered. Site construction is scheduled to ramp up in March 2015 with construction completion expected in September 2015. Commissioning and start-up of the CDU is scheduled to occur in Fourth Quarter 2015 with first-oil expected soon after.

FUTURE DEVELOPMENT

Following construction and start-up of Phase 1 of the PR Spring Project, the Company plans to develop additional modular phases as additional resources are developed and/or acquired. Individual modules can be built in various sizes ranging from 2,000 to 10,000 bbl/d or larger. Smaller sized modules may be built more quickly and will be more portable to allow redeployment to alternate processing locations. Larger-sized modules may be built at lower cost, benefitting from economies of scale. Current plans are to develop the existing known resource at PR Spring through two phases as outlined in Table 4.

Table 4: PR Spring Project Anticipated Project Development Program

Development	Capacity (bbl/d)	First Oil	Estimated Capital Cost ($MM)	Capital Intensity ($/bbl/d)
Phase 1[7]	2,000	2015	$60	$30,000
Phase 2[8]	10,000	2018	$175	$17,500

All permits required to build Phase 1 are currently in place. The addition of new mine pits using the same processing location may be achieved through amendments or revisions to the existing Large Mine Permit, and this is currently USO's intention.

Based on the successful trials of Athabasca bitumen with the SDU, the Company intends to use the technology and knowledge gained from the Utah operations to apply to mining opportunities in the Athabasca oil sands and in other global regions. The unique characteristics of the technology and low capital costs will allow its application in areas considered to be too small for traditional large scale oil sands mines. As discussed in this paper, USO's technology can be scaled to 10,000 barrels per day or less and still be economic. USO is currently evaluating opportunities in the Athabasca region and in other mining areas worldwide.

CONCLUSION

US Oil Sands Inc. has successfully incorporated a bio-solvent for the extraction of bitumen from mined oil sands. The technology eliminates the need for tailings ponds and requires significantly less capital than traditional extraction technologies. The PR Spring project in Utah is currently under construction and will be commissioned in Q4 2015 demonstrating commercial application of the bio-solvent technology.

NOMENCLATURE

$/bbl/d – Capital cost divided by production in barrels per day
$MM – Million dollars
$/bbl – dollars per barrel bitumen production
bbl/d or bbl/day – barrels of bitumen per day
CDU – Commercial Demonstration Unit (2,000 bbl/d)
MMbbls – Million barrels bitumen
SDU – Shop Demonstration Unit (25 bbl/d)
USO – US Oil Sands Inc.

REFERENCES AND NOTES

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5. Canadian Energy Research Institute, May 2008, *Green Bitumen: The Role of Nuclear, Gasification and CSS in Alberta's Oil Sands* – 30,000 bbl/d thermal *in-situ* project with a steam-oil ratio of 3:1.
6. Sproule Report, February 28, 2014.
7. Does not include commissioning and start-up costs.
8. Capital cost shown as the mid-point between the Company's $150 - $200 million estimated range.